PRODUCTION & CHARACTERIZATION OF MULTI-WALLED CARBON NANOTUBE (CARBOXYL - FUNCTIONALIZED) REINFORCED POLYESTERS

PRAKASH A/L JEGANMOHAN

Thesis submitted in partial fulfilment of the requirements

for the award of the degree of

Bachelor of Chemical Engineering (Hons)

Faculty of Chemical & Natural Resources Engineering

UNIVERSITI MALAYSIA PAHANG

JULY 2014

ABSTRACT

This paper presents the study on the production and characterization of Carbooxyl functionalized Multi-Walled Carbon Nanotube (MWCNT) reinforced Polyester composite. The main objective of this study is to optimize the weight percentage of MWCNT in the composite and to optimize the sonication time of the composite. To determine the optimum weight percentage of MWCNT, samples with different weight percentage of MWCNT was prepared. The prepared samples were sonicated for one hour and were tested for its viscosity. From the result, the viscosity was the highest at 0.4wt % MWCNT. Hence, the optimum weight percentage of MWCNT is at 0.4wt % MWCNT. After optimizing the weight percentage of MWCNT, the sonication time was optimized. This was done by preparing samples of 0.4wt % MWCNT which was then sonicated at different time intervals. After sonication, the viscosity was determined. From the result, the viscosity was the highest for the sample that was sonicated for 90 minutes. Hence, the optimum sonication time of 0.4wt % MWCNT is 90 minutes. After optimization, the composite was then characterized using Tensile Strength (TS) test, Thermal Gravimetric Analysis (TGA) and Fourier Transform Infrared Spectroscopy (FTIR). From the Tensile Strength test, it can be concluded that the composite with 0.4wt % MWCNT was stronger than the sample without MWCNT. Due to its high mechanical strength and other unique properties, this Polyester composite has the potential to be used in various applications.

Keywords: Polyester resin; Carbon nanotube; Viscosity; Dispersion; Ultrasonication

ABSTRAK

Kertas kerja ini membentangkan kajian mengenai pengeluaran dan pencirian komposit Poliester yang diperkukuhkan dengan Tiub Nano Karbon "Multi Walled" fungsi Karboksil (MWCNT). Objektif utama kajian ini adalah untuk mengoptimumkan peratusan berat MWCNT dalam komposit dan masa sonikasi komposit. Untuk menentukan peratusan berat optimum MWCNT, sampel dengan peratusan berat badan MWCNT yang berbeza telah disediakan. Sampel yang disediakan telah disonikasi selama satu jam dan diuji untuk kelikatan. Dari keputusan itu, kelikatan adalah yang tertinggi di 0.4wt % MWCNT. Oleh itu, peratusan berat optimum MWCNT pada 0.4wt % MWCNT. Selepas mengoptimumkan peratusan berat MWCNT, masa sonikasi oleh komposit telah dioptimumkan. Ini dilakukan dengan menyediakan sampel 0.4wt % MWCNT yang kemudiannya telah disonikasi pada jangka masa yang berbeza. Selepas sonikasi, kelikatan ditentukan. Dari keputusan itu, kelikatan adalah yang tertinggi bagi sampel yang disonikasi untuk 90 minit. Oleh itu, masa sonikasi optimum untuk 0.4wt % MWCNT adalah 90 minit. Selepas pengoptimuman, komposit itu kemudian dianalisis dengan menggunakan ujian Kekuatan Tegangan (TS), terma Analisis Gravimetrik (TGA) dan Spektroskopi Inframerah Transformasi Fourier(FTIR). Daripada ujian Kekuatan Tegangan, ia boleh disimpulkan bahawa komposit dengan 0.4wt % MWCNT lebih kuat daripada sampel tanpa MWCNT. Hal ini menunjukkan bahawa komposit Poliester ini mempunyai potensi untuk digunakan dalam pelbagai aplikasi.

Kata Kunci: Poliester; Tiub Nano Karbon; Kelikatan; Serakan; Ultrasonikasi

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

MWCNTs	Multi-Walled Carbon Nanotubes
MWCNT	Multi-Walled Carbon Nanotube
DWCNT	Double-Walled Carbon Nanotube
SWCNT	Single-Walled Carbon Nanotube
CNTs	Carbon Nanotubes
CNT	Carbon Nanotube
CB	Carbon Black
THF	Tetrahydrofuran
MEKP	Methyl Ethyl Ketone Peroxide
TGA	Thermal Gravimetric Analysis
FTIR	Fourier Transform Infrared Spectroscopy
TS	Tensile Strength
FKKSA	Fakulti Kejuruteraan Kimia & Sumber Asli
UMP	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In recent years, much effort has been placed on producing materials with unusual combination of properties that cannot be met with conventional ceramics, metal alloys and polymeric materials. This material which is known as composite materials or composites are materials made from two or more constituent materials with relatively different properties, in which when combined, produces a new material with significantly improved properties that is different from the individual materials.

Composites are preferable due to its improved mechanical, physical and chemical properties. In addition, they are also stronger, lighter and might also be less expensive when compared to conventional materials such as ceramics, metal alloys and polymeric materials.

Composite materials are generally made up of two phases which are the matrix phase and the reinforcement phase. The individual components in the composite normally remain separate and distinct within the structure. Generally, the matrix phase is comprised of resins such as polyester or epoxy which are continuous phase whereas the reinforcement phase is made of various kinds of fibers. In this study, the resins used are Polyester Resin and the fiber used is Carbon Nanotube (CNT) which is Carboxyl (COOH) functionalized.

1.2 Motivation

Carbon Nanotube (CNT) has the potential to be accepted as advanced materials for the upcoming generation. This is due to its excellent properties such as high thermal conductivity, high mechanical strength and good electrical properties. Fundamental research progressed to date suggests that CNT is regarded as promising reinforcements in the polymer composites due to the combination of their uniquely excellent properties with high aspect ratio and small size (Ebbesen, 1994).

The discovery of multi-walled carbon nanotubes (MWCNTs) in 1991 has stimulated ever-broader research activities in science and engineering devoted entirely to carbon nanostructures and their applications (Iijima, 1991). Since the discovery of CNT in 1991 by Iijima, CNT has attracted a lot of researches to do research for its potential applications in a broad range of industry. For an instance, Ma et al. (2003) synthesized CNT/polymer systems using polyester. However, due to limited availability and higher cost, there are only a few practical applications in industrial field.

Dispersion of nanofillers plays a very important role in the use of filler properties in polymeric composites. Nanoparticles due to large surface area and mostly high aspect ratio tend to agglomerate greatly which reduces the ability to show their expected properties (Peigney et.al, 2001). A technique to achieve good dispersion of nanoparticles is ultra-sonication which can be used also for CNTs. Applying this method in a low-price polymer-like polyester which has good properties such as versatileness, quick curing, and low viscosity leads to fabrication of CNT/polyester composite with enhanced properties.

According to Aurilia et al. (2012), CNT addition into polymeric materials is a valuable solution in performances enhancement, when adequately dispersed. Nevertheless, in this research, the incorporation of CNT in polyester was studied due to the interest in improving the properties of the polyester for various applications.

1.3 Problem Statement

According to the literature, there were some drawbacks that were faced by various researches on producing Carbon Nanotube (CNT) reinforced Polyester composite

materials. Firstly, CNT tends to bundle together and to form some agglomeration due to intrinsic van der Waals attraction between the individual tubes (Dresselhaus et al., 2001).

Secondly, weak interfacial bonding between the nanotubes and the polymer matrix has limited the efficient load transfer to the polymer matrix, playing a limited reinforcement role in the polymer nanocomposites (Lourie et al., 1998).

Hence, in this study, both problems would be eliminated or reduced by optimizing the weight percentage of CNT in the composite and by optimizing the sonarification time. This could produce a new composite with improved properties.

1.4 Objectives

There are two main objectives in this study:

a) To obtain the best dispersion of Carbon Nanotube (CNT) in Polyester resin
b) To produce Carbon Nanotube (CNT) Reinforced Polyester

1.5 Scope

This study will be focusing on the production of Carbon Nanotube (CNT) Reinforced Polyester and the characterization of the composite. The area of study narrows to the following:

a) To determine the optimum weight percentage of Carbon Nanotube (CNT) in the composite without using any solvent
b) To determine the optimum weight percentage of Carbon Nanotube (CNT) in the composite by using Tetrahydrofuran (THF) as solvent
c) To determine the optimum sonication time needed for Carbon Nanotube (CNT) & Polyester composite
d) To characterize the composite using various analysis such as Viscometer, FT-IR spectral analysis, Thermal Gravimetric Analysis (TGA), and Tensile Test.

CHAPTER 2

LITERATURE REVIEW

2.1 Composites

Many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials. Material property combinations and ranges have been, and are yet being, extended by the development of composite materials. Generally speaking, a composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such as that a better combination of properties is realized. (Callister & Rethwisch, 2008).

A composite, in the present context, is a multiphase material that is artificially made, as opposed to one that occurs or forms naturally. In addition, the constituent phases must be chemically dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiple phases are formed as a consequence of natural phenomena.

In designing composite materials, scientists and engineers have ingeniously combined various metals, ceramics, and polymers to produce a new generation of extraordinary materials. Most composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness, and high temperature strength.

Many composite materials are composed of just two phases; one is termed the matrix, which is continous and surrounds the other phase, often called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and the geometry of the dispersed phase. “Dispersed phase geometry” in this context means the shape of the particles and the particle size, distribution, and orientation.

2.1.1 Fiber-Reinforced Composites

Technologically, the most important composites are those in which the dispersed phase is in the form of a fiber. Design goals of fiber-reinforced composites often include high strength or stiffness on a weight basis. These characteristics are expressed in terms of specific strength and specific modulus parameters, which correspond, respectively, to the ratios of tensile strength to specific gravity and modulus of elasticity to specific gravity. Fiber-reinforced composites with exceptionally high specific strengths and moduli have been produced that utilize low-density fiber and matrix materials. (Callister & Rethwisch, 2008).

2.1.1.1 Influence of Fiber Length

The mechanical characteristics of a fiber-reinforced composite depend not only on the properties of the fiber, but also on the degree to which an applied load is transmitted to the fibers by the matrix phase.

Some critical fiber length is necessary for effective strengthening and stiffening of the composite material. This critical length, l_c is dependent on the fiber diameter, d and its ultimate strength σ_f , and on the fiber-matrix bond strength (or the shear yield strength of the matrix, whichever is smaller) τ_c according to

$$l_c = \frac{\sigma f d}{2\tau c}$$

For a number of glass and carbon fiber-matrix combinations, this critical length is on the order of 1mm, which ranges between 20 and 150 times the fiber diameter. As fiber length l increases, the fiber reinforcement becomes more effective.

Fibers for which $l \gg l_c$ (normally $l > 15l_c$) are termed continous; discontinuous or short fibers have lengths shorter than this. For discontinuous fibers of lengths significantly less than l_c , the matrix deforms around the fiber in such a way that there is virtually no stress transference and little reinforcement by the fiber. For a significant improvement in strength of the composite, the fibers must be continuous.

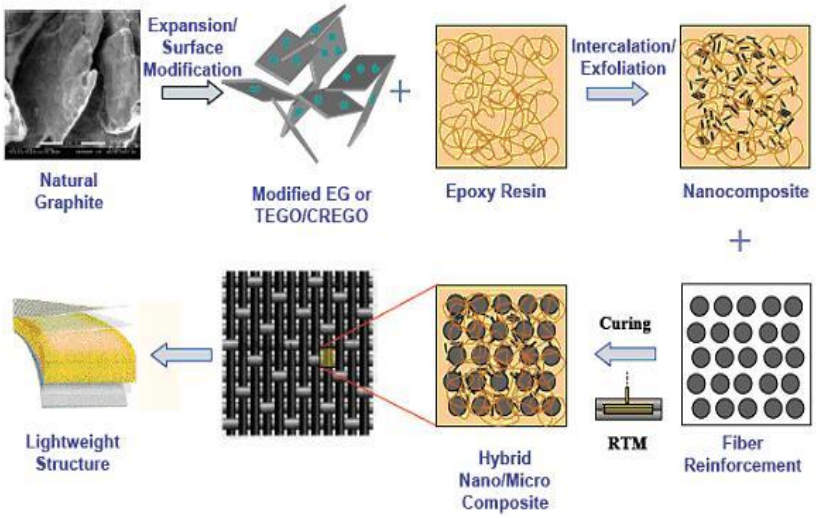

Figure 2.1 Fiber reinforcement in Epoxy Resin

2.1.1.2 Influence of Fiber Orientation

The arrangement or orientation of the fibers relative to one another, the fiber concentration, and the distribution all have significant influence on the strength and other properties of fiber-reinforced composites. With respect to orientation, two extremes are possible:

i) Continuous and Aligned Fiber Composites
ii) Discontinuous and Aligned Fiber Composites
iii) Discontinuous and Random Fiber Composites

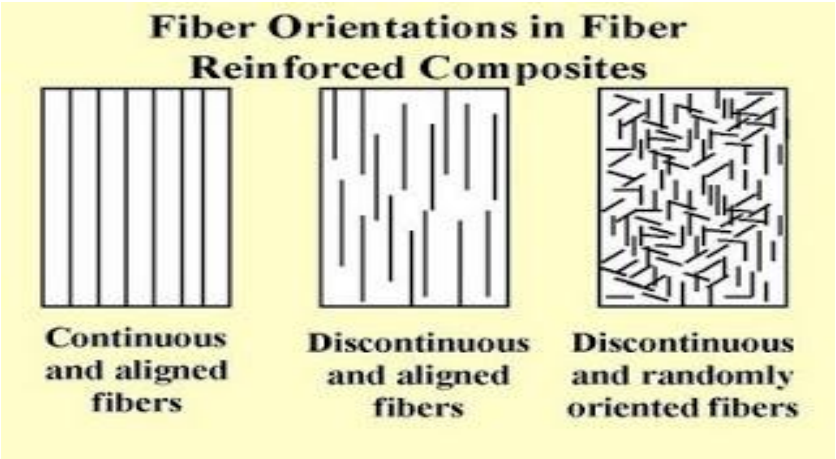

Figure 2.2 Fiber Orientations in Fiber-reinforced composites

2.2 Carbon Fiber-Reinforced Polymer (CFRP) Composites

Carbon is a high-performance fiber material that is the most commonly used reinforcement in advanced polymer-matrix composites. The reasons for this are as follows:

- Carbon fibers have the highest specific modulus and specific strength of all reinforcing fiber materials.
- They retain their high tensile modulus and high strength at elevated temperatures; high temperature oxidation, however, may be a problem.
- At room temperature, carbon fibers are not affected by moisture or a wide variety of solvents, acids, and bases.
- These fibers exhibit a diversity of physical and mechanical characteristics, allowing composites incorporating these fibers to have specific engineered properties.
- Fiber and composite manufacturing processes have been developed that are relatively inexpensive and cost effective.

Carbon fibers are not totally crystalline, but are composed of both graphitic and noncrystalline regions. Besides that, carbon fibers are normally coated with a protective epoxy size that also improves adhesion with the polymer matrix.

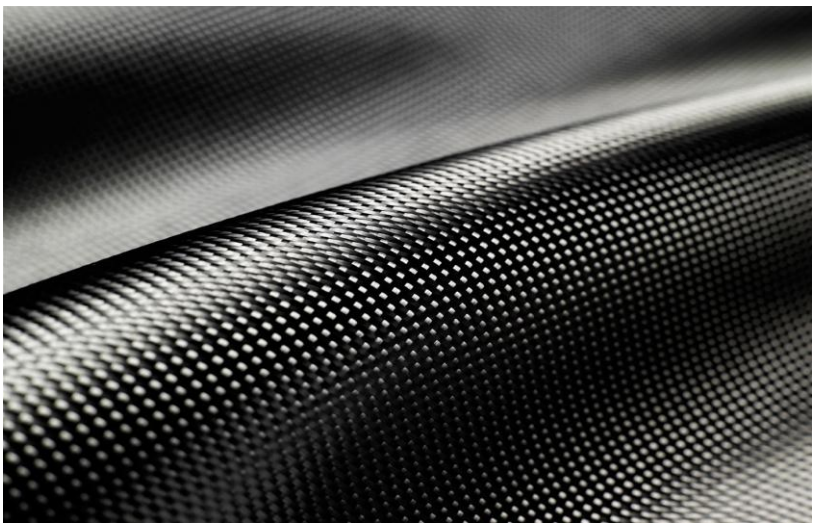

Figure 2.3 Application of Carbon Fiber in Automobile Industry

Carbon-reinforced polymer composites are currently being utilized extensively in sports and recreational equipments (fishing rods, golf clubs), filament-wound rocket motor cases, pressure vessels, and aircraft structural components- both military and commercial, fixed wing and helicopters (e.g., as wing, body, stabilizer, and rudder components). (Callister & Rethwisch, 2008).

2.3 Polyester Resin

Polyester resins are unsaturated resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Polyester resins are used in sheet moulding compound, bulk moulding compound and the toner of laser printers. Wall panels fabricated from polyester resins reinforced with fiberglass — so-called fiberglass reinforced plastic (FRP) — are typically used in restaurants, kitchens, restrooms and other areas that require washable low-maintenance walls.

Unsaturated polyesters are condensation polymers formed by the reaction of polyols (also known as polyhydric alcohols), organic compounds with multiple alcohol or hydroxy functional groups, with saturated or unsaturated dibasic acids. Typical polyols used are glycols such as ethylene glycol; acids used are phthalic acid and maleic acid. Water, a by-product of esterification reactions, is continuously removed, driving the reaction to completion.

Unsaturated polyester resins are further classified into the following categories:

- Ortho-phthalic polyesters – resins made from ortho-phthalic anhydride are generally cheaper than the other two classes of unsaturated polyester resins. They are usually used to manufacture general purpose composite laminates where only moderate structural properties are required.
- Iso-phthalic polyesters – resins made from Iso-phthalic acid. These resins are much more structurally competent than the ortho-phthalic resins. They also have superior corrosion resistance and are used for more demanding applications
- Tere-phthalic polyesters – Tere-phthalate resins are made from tere-phthalic acid. These resins are currently made in small volumes and are considered a specialty resin. Although they tend to have better thermal and chemical resistance than iso-phthalic resins they are difficult to manufacture.

Figure 2.4 Polyester Resin

The use of unsaturated polyesters and additives such as styrene lowers the viscosity of the resin. The initially liquid resin is converted to a solid by cross-linking chains. This is done by creating free radicals at unsaturated bonds, which propagate in a chain reaction to other unsaturated bonds in adjacent molecules, linking them in the process. The initial free radicals are induced by adding a compound that easily decomposes into free radicals. This compound is usually and incorrectly known as the catalyst. Substances used are generally organic peroxides such as benzoyl peroxide or methyl ethyl ketone peroxide.

Recently there has been a global focus on greener processes and technologies. This is where unsaturated polyesters have the most potential over their metallic counterparts. Production of metals continues to deplete our natural resources and consumes most of our fossil fuels. Unsaturated polyesters although previously synthesized from fossil fuels can now be manufactured from biological resources instead. Starches, plant oils and other naturally derived building blocks have been discovered that can be used to prepare unsaturated polyester resins.

2.3.1 Characteristics of Polyester Resin

The material has the potential to be 100 percent solid. This depends on how fast the reaction takes place. The styrene is volatile prior to the reaction. Heat is not typically added to the system except when cure time is expected to be long, such as on cool spring or fall days. The catalyst is added to drive the reaction. Usually, the catalyst is methyl ethyl ketone (MEK) or benzoyl peroxide. The polyester resin and the styrene solvent react together to crosslink, or polymerize, to form a film. The polyester resin system will not cure properly if the appropriate quantity of catalyst is not added.

Unsaturated polyester resins also have excellent service temperatures. They have good freeze-thaw resistance and can be designed for use in many low to moderate temperature applications ranging from refrigerated enclosures to hot water geysers.

2.3.1.1 Advantages of Polyester Resin

Polyester resin is the resin that mainly preferred in industries; this is because it got a lot advantages. The advantages are:

Advantages

- Essentially two components in one container
- Long lasting and durable
- Does not discolor badly
- Relatively inexpensive
- Works well on concrete

2.3.1.2 Disadvantages of Polyester Resin

Although, there are a lot advantages of using polyester resin, it still has some disadvantages. The disadvantages are:

Disadvantages

- Peroxide catalyst is a very reactive oxidizer
- Requires placarding as a hazardous material

- Requires commercial drivers license
- Flush solvent is flammable and a hazardous waste
- Moisture in surface a major factor and detriment
- Set up time depends on type of resin (usually 3-20 minutes)
- Difficult to determine whether mixed properly

2.3.2 Classification of Polyester

Polyesters were broadly classified into unsaturated and saturated polymers. These were two broad divisions subdivided as follows: (Bruins, 1976)

1. Unsaturated

a) Laminating and Casting Resins. These were based on dibasic acids and dihydric alcohols. The polyester unit formed must be capable of copolymerizing with a vinyl-type monomer, thereby yielding a vinyl-polyester copolymer or simply cured polyester having a thermoset structure.

b) Alkyds. In general, the same types as (a) although the glyptal (surface coatings) types are modified with oils or fatty acids. This term was also used to describe a group of thermosetting moulding materials based on the reaction of a dihydric alcohol with an unsaturated acid such as maleic in place of the conventional phthalic acid. A vinyl type monomer was also necessary to affect speedy cross-linking and curing and used as moulding powders for compression and transfer-moulding techniques.

2. Saturated

a) Fibres and Films. These were based on the reaction of terephthalic acid with ethylene glycol and were linear, high molecular weight polymers which do not undergo any cross-linking reactions.

b) Plasticizers. These were polyesters which were completely saturated, normally referred to as polymeric plasticizers.

c) Polyester/ Polyurethanes. Certain polyesters having high hydroxyl content were reacted with various isocyanates to form polyurethanes, which were finding extensive use as foams, elastomers, surface coatings and adhesives.

2.3.3 Synthesis of Polyester Resin

Polyesters were polymers with repeating carboxylate groups in their backbone chain. The polyester backbone was generally composed of three basic types of structural units, saturated acids, unsaturated acids and glycols (Figure 2.5).

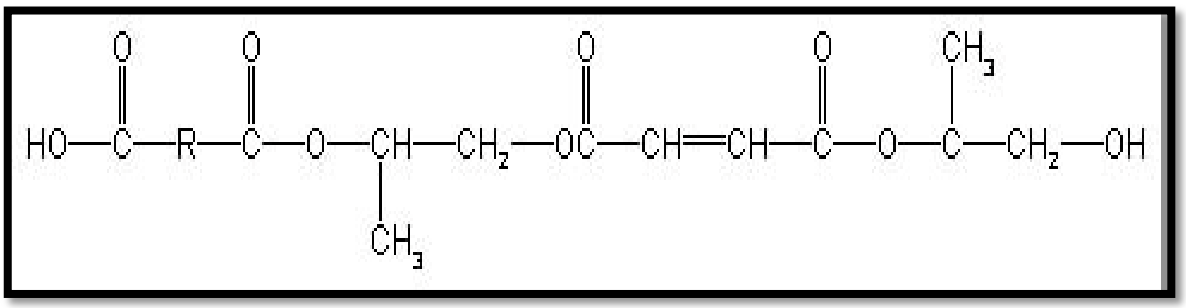

Figure 2.5: Anhydrides Acid, Acids, Unsaturated Anhydrides Acids and Alcohols Formed Polyester. Birkley, (1989)

In the case of the general-purpose polyester, these components usually consisted of phthalic acid, maleic acid, and propylene glycol. This was a very desirable composition since it had the characteristics of low cost and good quality; propylene glycol and phthalic anhydride were the lowest cost raw material in their class. The unsaturated acid provided the sites for cross-linking, the saturated acid determined the degree of spacing and the glycol, of course, provided the means for esterification and for bridging the acids to form a polymer. Linear unsaturated polyesters were prepared batch wise by heating and cooling and fitted for distillation. A typical formulation for a general-purpose material were as follows; propylene glycol, 100 parts by weight, maleic anhydride, 72 parts by weight and phthalic anhydride 54 parts by weight.

First produced commercially in the late 1920s, polyesters have become important compounds used in a wide variety of industries. The most economically important types of polyesters include poly (ethylene terephthalate) (PET) and poly (butylene terephthalate) (PBT). The chemical reactions for making polyesters were investigated in 1901 and resulted in the production of glyptal polyesters. These reactions involved the combination of a diacid with a diol. The reaction was called a condensation reaction because the two initial types of monomers combined to produce a longer chain polymer and water as a by product.

Linear polyesters were not produced until the 1930s, when W. H. Carothers systemically investigated reactions of diols with diacids. Carothers was not successful in producing a polyester fiber and switched the focus of his research. In 1942, John Whinfield and W. Dickson made the first high molecular weight PET. After these fibers were produced other polyesters were discovered and have since become very important compounds (Beier et.al, 2007).

Linear unsaturated polyesters were prepared commercially by the reaction of a saturated diol with a mixture of an unsaturated dibasic acid and a modifying dibasic acid. In principle, unsaturation desired in a polyester can be derived from either an unsaturated diol or an unsaturated acid provides sites for subsequent cross-linking; the function of the modifying acid was to reduce the number of reactive unsaturated sites along the polymer and hence to reduce the cross-link intensity and brittleness of the final product. Some acids and anhydrides which were used to modify polyester are, in fact, unsaturated but the double bonds were not sufficiently reactive to represent sites for subsequent cross-linking (Saunders, 1988).

Unsaturated polyester resins were addition products of various saturated acids, unsaturated acids and glycols. Many patents for the preparation of these products were issued within the past 30 years. The polymers making up this first group of polyesters were linear polyesters containing aliphatic unsaturation which provided sites for subsequent cross-linking. A polymer of this type first became available in the U.S.A in 1946; the polymer was prepared from diethylene glycol and maleic anhydride and could be crosslinked by reaction with styrene (Saunders, 1999).

2.3.4 Current Interest Research of Unsaturated Polyester

Polyesters were important class of high performance and engineering polymers, which find use in a number of diverse applications (Barbiroli et al., 2003; Aziz et al., 2005; Qazvini & Mohammadi, 2005). Unsaturated polyester resin were chosen first for making fibre reinforced plastics (FRP) by any molder because of the ease of handling and fabrication and the low cost as compared to epoxy resin. They were primarily used in compression molding (sheet molding compounds), injection molding (bulk molding compounds), resin transfer molding, pultrusion, filament winding and hand lay-up

process (Vilas et al., 2001). About 85% of the FRP products like boats, car and aircraft components and chairs) were manufactures using polyesters (Devi et al., 1997).

Different kinds of polyesters were synthesized over the past decades from various types of diacid chlorides and diols. Thermally stable polyesters derived from isophtalic and terephthalic acids with bisphenol-A was commercialized (Ramakrishna, 2005). However, polyesters were generally difficult to process because of their limited solubility in organic solvents and their melting temperature or high glass-transition temperature by virtue of their rigid structures (Tamami et al., 2004). Therefore development of polyesters for use at high temperature with improved solubility was an important goal.

One of the approaches to improved solubility as well as processability of the polymers without extremes loss of their high thermal stability was the introduction of polar and flexible groups into the polymer backbone (Messori et al., 2001; Ito et al., 2001; He et al., 2001; Aziz et.al, 2004; Huang & Jiang, 1998). The incorporation of bulky pendent groups were also provided beneficial effect for solubility because this approach produces a separation of chains and lowering the chain packing with a molecular mobility, so that the overall observable effect improvement of solubility at the same time (Tsubokawa et al., 1983; Xueqiu et al., 1988; Walter et al., 1995; Lange et al., 1997; Grobelny, 1997). It was well known that a large number of polymers containing heterocyclic ring in the main chain were resistant to high temperature (Blumstein et al., 1982).

Recently, the researchers synthesized new polyesters containing rigid segment such as pyridine rings that possess high glass transition temperatures and enhanced solubility in organic solvents (Chen et al., 2005). Current interest in unsaturated polyester (UP) resins also focused on the enhancement of chemical inertness, solvent and high temperature resistant, barrier properties, low friction coefficient and low surface tension, that in principle were transferred to other polymeric materials by blending or copolymerization. Some enhancement such as excellent resistance to corrosion, water and atmospheric agents, formulations for resins and foams and several others were also reported in patent literature (Messori et al., 2001).

Unsaturated copolyesters, also called polyester resins, were based on macromolecules with a polyester backbone in which both a saturated acid and unsaturated acid were

condensed with a dihydric alcohol (Qazvini & Mohammadi, 2005). A survey of the scientific literature reveals that few unsaturated copolyesters based on the interaction of unsaturated diols and saturated acids were synthesized and studied (Tiitu et al., 2005). Imai and Tassavori synthesized and studied aromatic polyesters and copolyesters containing phenylindane units with Tg 235- 253ºC (Messori et al., 2001).

The present investigation deals with the synthesis and characterization of new unsaturated polyesters and co-polyesters based on some dibenzylidenecycloalkanones and containing meta- and para-azo groups in the main chain. A major purpose of this work was to investigate the effect of a cycloalkanone ring, in the polymer backbone, on polymer properties.

2.4 Carbon Nanotube (CNT)

In 1981 a group of Soviet scientists published the results of chemical and structural characterization of carbon nanoparticles produced by a thermocatalytical disproportionation of carbon monoxide. Using TEM images and XRD patterns, the authors suggested that their "Carbon multi-layer tubular crystals" were formed by rolling graphene layers into cylinders.

The last few years have witnessed the discovery, development and, in some cases, large-scale manufacturing and production of novel materials that lie within the nanometer scale. Such novel nanomaterials consist of inorganic or organic matter and in most cases have never been studied in the context of pharmaceuticals. Carbon verynanotubes (CNTs) are one of them. CNTs are allotropes of carbon. They are tubular in shape, made of graphite. CNTs possess various novel properties that make them useful in the field of nanotechnology and pharmaceuticals. They are nanometers in diameter and several millimeters in length and have a very broad range of electronic, thermal, and structural properties. These properties vary with kind of nanotubes defined by its diameter, length, chirality or twist and wall nature. Their unique surface area, stiffness, strength and resilience have led to much excitement in the field of pharmacy (Lacerda et.al, 2006).